# THE IMPACT OF FARM MECHANIZATION ON SMALL-SCALE RICE PRODUCTION

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ABSTRACT

TAN, YOLANDA L., University of the Philippines at Los Baños, March 1981. The Impact of Farm Mechanization on Small-scale Rice Production. Thesis adviser: Dr. Bart Duff.

The objective of this study is to quantitatively assess the impact of farm mechanization on output. Production effects of mechanization were evaluated through the use of decomposition analyses. First, an arithmetic decomposition analysis was employed to disaggregate output differences between mechanized and non-mechanized farms into its component elements, i.e., yield, price, area and cropping intensity component plus the interactions of these components. Results of the analysis showed that the most important factors that brought about output differences between the mechanized and non-mechanized farms were cropping intensity and yield.

Secondly, yield effect of mechanization was investigated by using another decomposition technique employing a production function framework. The model decomposed total yield differences between the mechanized and non-mechanized farms into the technological change component and change in the use of inputs component. The results of the analysis showed that the major source of yield differences between the two farm types was

brought about by non-neutral technical change, i.e., shift in the slope coefficients of the production functions, which means differences in the allocation of resources of the two farms.

# CHAPTER I

# INTRODUCTION

Technological advancement is one of the important forces which alters the production structure of a growing economy. The significance of technological change is that it permits continuous improvement in the productivity of resources by the constant flow of innovations and skills for resource utilization. Technological changes may call for readjustments of resources employed in the agricultural sector relative to the other sectors of the economy. New technology, therefore disturbs the equilibrium of the receiving environment and can result in a chain of complex technical, economical, social, cultural and institutional effects that are neither easily predictable nor necessarily consistent with the aims of rural development.

## 1.1 Problem

The term "technical change" means broadly any change relevant to productivity growth and is commonly accepted as basic to any meaningful policy for economic development of the agricultural sector. Analyzing, therefore, the effects of the existing technologies will help to effectively improve and tailor new technological possibilities to the needs of rural development.

Mechanization of small farms, as a form of technical change in developing countries, is frequently equated with modernization. Faced, therefore, with a growing rural labor force and increasing demand for food, the development, introduction and use of agricultural machines in LDCs had produced a large and controversial literature describing technical, economic, socio-anthropological attempts to quantify, measure and evaluate the impact of mechanization on farm output, employment and income distribution. For example, there appear too few rigorous studies which demonstrate conclusively and convincingly the net effect of mechanical techniques. This study, therefore, will try to measure quantitatively and analyze the output effects of mechanization.

Farm mechanization has been the center of a continuing controversy for many decades now. The focal point of these debates centers around five major issues:[1/]

1. does mechanization increase farm productivity (yield/hectare and yield/hectare/year) if so, how?

2. to what degree is labor displaced by machines and what are the alternative employment opportunities for that displaced

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[1/] The Consequences of Small Rice Farm Mechanization on Production, Incomes and Rural Employment in Selected Countries of Asia (A Project Proposal), IRRI, February 1978.

labor?

3. to what extent are the benefits of mechanization concentrated in the better endowed sectors of the rural society?

4. with the rising prices of fuel energy, is it still economical to mechanize?

5. what policies should the government follow to obtain the desirable benefits of mechanization while minimizing the undesirable effects?

## 1.2 Objectives

Given the five major farm mechanization issues, this study will address itself only to the first one. It aims to develop a methodology to resolve the question of whether mechanization increases output or not. This will be done by analyzing the effects of mechanization on output using decomposition analysis which will partition total observed output differences between mechanized and non-mechanized farms into the factors that brought about such differences.

## 1.3 Hypotheses

Mechanization as an input, holding water availability and seed variety constant could be investigated as to whether it increases output or not. Evidence from Thailand (Inukai, 1970), Nepal (Thapa, 1979) and Philippines (Antiporta and Deomamapo, 1979) showed that output from mechanized farms was higher than non-mechanized farms. The observed differences in output between these farms could be due to the differences in yield, area cultivated and cropping intensity of the two farm types.

With respect to output differences attributed to mechanization, the following hypotheses were tested:

1. The adoption of farm machinery increases yield holding all other inputs constant.

2. Mechanization increases cropping intensity.

Output differences between mechanized and non-mechanized farms could also be due to changes in the factors of production or inputs used and a shift in technology. In this study, technical change was taken to mean mechanization of small rice farms.

The impact of technical change could be decomposed into two components: (1) an efficiency component (neutral technical change) i.e., more output could be produced under the new production technology with the same level of inputs, and (2) an adjustment component (non-neutral technical change) i.e., the efforts of farmers to reallocate the use of inputs at the new level of efficiency. This study likewise searched for the sources of output differences between mechanized and non-mechanized farms. Specifically, it tested the following hypotheses:

3. The output differences between mechanized and non-mecha-

nized farms are due to neutral technical change or increased efficiency in production.

4. The output differences between these two farm types are brought about by non-neural technical change which implies reallocation in the use of inputs in the production processes.

# CHAPTER II

# REVIEW OF LITERATURE

This section surveys the literature on the history of the growth of farm mechanization in the Philippines, production effects of mechanization and the decomposition techniques used by various authors as a method for the component analysis of output growth.

## 2.1 History of the Growth of Farm Mechanization in the Philippines

Agricultural mechanization in the Philippines began as early as in the final years of the Spanish period with the importation of disc harrows, cultivators, gang-plows and corn planters (Santos, 1946). At the end of World War I (1918), tractor mechanization was mainly concentrated on large sugar cane plantations, although large mechanical stationary threshers powered by four-wheel and crawler tractors were reported to have been introduced and used during the late 1930's. After World War II (1946), with the government efforts to foster mechanization through the exemption of farm machinery imports from custom duties, special import taxes and countervailing duties (Piputsitee, 1976), the country was able to import an average of 650 tractors annually (Follosco, 1966). These machines coming from the industrialized countries were, however, considered inefficient and costly because they were basically developed for different conditions of either large farm holdings and higher labor costs as in the United States, or for subsidized small farms as in Japan which was far from the agro-economic situation of the country. As a result, farm mechanization was insignificant prior to 1960. Another reason for the slow adoption of farm mechanization during these years was the country had a surplus of agricultural land, hence agricultural production could be increased through the opening of new land and increased use of necessary inputs. But with the closing of the land frontier during the 1960's, a significant shift in resource use in agriculture took place, requiring innovations that would result to increase in land productivity or yield per hectare (Crisostomo and Barker, 1972).

A census of farm machinery dealers in 1960 reported that 50% of the 8,500 tractors in the country were owned by the large sugar farmers, 35% by rice farmers and 15% by other crop farmers (Almario, 1979). This relatively high tractor use by sugar farmers during the years 1962-64 could be related to the sugar industry boom resulting from the United States embargo placed on Cuban sugar imports resulting in higher prices for Philippine sugar (Duff, 1975).

In the late 1960, there was increased tractor mechanization especially in rice production brought about by the government's adoption of credit programs and the advent of high yielding varieties which raised farm incomes and improved investment potentials for mechanical technology. Concurrently, power tillers or hand tractors were introduced primarily for land preparation.

In 1965, the International Rice Research Institute (IRRI) initiated a USAID funded research and development program to produce a range of small low cost machine designs which would enhance the production possibilities of small rice farmers. The goal was to develop equipment which could be manufactured and maintained locally, and which could be within the investment capabilities of farmers with landholdings of 2 to 5 hectares.

After fifteen years of research and development, a number of IRRI designs have entered commercial production. At present, IRRI together with the private manufacturers of farm machineries are attempting to strengthen further the research and development programs for agricultural mechanization tailored to the needs of small rice farmers in Asia (McMennamy, 1976).

## 2.2 Related Literature on Production Effects of Mechanization

The use of farm machineries in less developed countries presents two opposing views. On the one hand, farm mechanization allows a faster, less laborious and timely operations of farm tasks which is claimed to lead both to increased yields and greater intensity of land use. It is also argued to increase labor productivity and income.

On the other hand, it is often seen as a direct substitute for labor which is undesirable in places with extensive labor supply, often the case of less developed countries. Agricultural mechanization, however, may supplement, substitute or complement other factors in the production process (Duff, 1978) depending on the type of machines used.

It could be a substitute for labor and animal power as in the case of tractors; a supplement, as in the case of rotary weeders, fertilizer applicator and insecticide/weedicide sprayers; and a complement as in the case of irrigation pumps in rainfed areas.

Production effects of mechanization could be viewed in terms of cropping intensity, cropping pattern and yield effects. In a review of tractor studies in India[2/], cropping intensity was higher on tractor farms than the bullock farms in 30% of the cases reviewed. This intensity advantage of tractor farms was not necessarily caused by tractorization since most of the cases which reported increased cropping intensity was observed to be

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[2/] Binswanger, H. Economics of Tractors in South Asia, ADC, New York and ICRISAT, Hyderabad, India, 1978, pp. 19-30.

paralleled with improved irrigation facilities. Therefore, the studies reviewed, taken together, gave little support to the hypothesis that tractorization is an important factor in increasing cropping intensity.

In the case of cropping pattern, an impressive advantage was observed from these studies[3/] for tractor farms. Further analysis, however, showed that this was also due to variety of facrors other than tractorization, such as access to capital and water availability. In a recent study of Patel (1980), the order of priority of crops studied in the cropping pattern of tractor and bullock farms in Gujarat, India was the same. This implied that cropping pattern was not affectd by the tractorization of the farms.

Yield advantages of tractor farms appeared to be large in more than 50% of the studies cited[4/]. However, in most of the reported cases, fertilizer use was also higher in the tractor farms. This higher yield in the tractor farms, therefore, was not exclusively due to tractorization.

Assessing the existing studies and researches on tractorization in less developed countries, the tractor surveys resulted to

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3/ Ibid., pp. 42-47

4/ Ibid., pp. 30-37

inconclusive evidences that tractors are responsible for significant increases in cropping intensity, yields, cropping patterns and gross returns on farms. There is, therefore, a need to quantitatively measure the impact of tractorization on output, employment and income distribution to conclusively evaluate the net effects of mechanical techniques.

## 2.3 Survey of the Literature on Decomposition Analysis

Decomposition analysis or component analysis is a mathematical technique for partitioning an aggregate into its component elements. Early studies have applied the decomposition technique to investigate the effects of technological change on output growth (Solow, 1957), an important factor that received attention in the earlier literature. In this pioneering work of Solow, a geometric productivity index was presented, which was a substantial refinement over the previous arithmetic index of Abramovitz (1956).

The Solow index was formally derived from a general production function. Assuming perfect competition, the process tried to measure technological change by decomposing output growth into explanatory components which are actually changes in inputs used, i.e., capital and labor, weighted by their respective factor shares and a residual term which was a measure of technical change.

Decomposition analysis was likewise used to allocate differences in productivity resulting from a variety of factors such as the extension of cultivation to new areas due to reclamation of virgin land and deforestation, and increases in cropping intensity made possible by the spread of irrigation and adoption of better crop rotations (Minhas and Vaidyanathan, 1965).

The component analysis of output growth used for the first time by Minhas and Vaidyanathan was an additive scheme of decomposition. Change in aggregate output was decomposed into four components, i.e., the contribution of:

a. changes in area
b. changes in per acre yield
c. changes in cropping pattern
d. the interaction between yield and cropping pattern

The Minhas-Vaidyanathan framework is one of the several additive methods of decomposition analysis. In addition to the additive schemes, one can also decompose output into different component elements in a multiplicative fashion. The results obtained, however, from the multiplicative decomposition scheme are not as easy to interpret as in the additive scheme. This framework involved interaction terms of component elements which mean simultaneous effects of the components.

More recent studies have used decomposition techniques for decomposing output growth in Gujarat (Misra, 1971) and for a comparative analysis of the pre-Green Revolution periods in India (Sonhdi and Singh, 1975). Both studies used a slightly modified version of the original Minhas and Vaidyanathan model in so far as an interaction term between area and other components was added.

Decomposition analysis was also used to quantify the employment effects of technical change (Krishna, 1974), which was taken to mean changes in water availability, cropping intensity, seed varieties, fertilizer use and the degree of mechanization. The model was used to decompose total labor input into:

a. irrigation effect
b. variety effect
c. tractor-ploughing effect
d. irrigation technology effect
e. threshing effect
f. interaction effects of irrigation and varietal improvement

The framework allowed for the grading of each individual technical change according to the magnitude of its positive and negative employment effects.

Output growth was further investigated by Sagar (1977) who tried to decompose overall productivity of crops into a price effect, yield effect, cropping pattern changes and the interactions of these components. Narain (1977) also used a framework similar to that of Sagar, only it was more specific with respect to crop types and for different states.

Another decomposition technique was used by Bisaliah (1977) in analyzing factors affecting output growth, this time using a production function framework. He decomposed the total change in yield due to the introduction of new production technology into the proportion brought about by technical change and the proportion due to the change in the input levels.

Bisaliah (1978) also employed a decomposition technique to evaluate the total employment effects of technical change. Using a labor demand function derived through a unit-output-price profit function, the total change in employment between new and old technology farms was decomposed into:

a. a technology component

b. a wage rate component, and

c. a complementary inputs component.

Binswanger (1978) presented a decomposition technique that disaggregated output growth into cropping intensity, yield, cropping pattern effects and an R-term. The R-term, which is actually the residual term, was regarded simply as approximation errors arising out of the switch from the continuous function to the discrete formulation.

Rathore (1979) verified Binswanger's decomposition scheme by using the model to disaggregate total observed differences in output between small and large farms. The analysis resulted in large, unacceptable residuals and another decomposition model without residual was suggested (Binswanger, 1979).

Assessing the literature on decomposition analysis, little has been done to evaluate output and employment differences that might result from mechanization.

Decomposition analysis is one of the many methodologies that can evaluate the effects of mechanization on production (Binswanger, 1978) and employment (Krishna, 1974). The technique could be designed to allocate the observed output and employment differences between farms "before and after" or "with and without" certain machines into the following component elements viz. cropping intensity, yield, cropping pattern and price. This partitioning shows the relative importance of component effects, thus enabling the analyst to identify the most fruitful areas for further investigation.

The decomposition technique may be an arbitrary scheme, but at the back of it is an analytical design (Minhas and Vaidyanathan, 1965). In this scheme component elements, i.e., cropping intensity, cropping pattern, yield and price are chosen and arranged in a manner such that their individual effects can be additively aggregated. Each factor can be separately analyzed to provide measures of output growth brought about by their absolute changes. This allocation of output differences into its component elements is useful in providing guidance in identifying the important factor(s) that brought about such output differences. Together with the information about differences in irrigation, cropping pattern and modern package of technology like HYV, fertilizers, pesticides, etc., a picture of the output effects of a given machine can be constructed.

# CHAPTER III

## RESEARCH METHODOLOGY

In evaluating whether mechanization increases output or not, decomposition analyses was employed to explain the observed output differences between farms "with and without " mechanization in terms of its component elements.

### 3.1 Decomposition Model I

Output between mechanized and non-mechanized farms was investigated and tested for differences using the Kruskal-Wallis one-way analysis of variance by ranks[5/]. Having shown that there is a statistical difference in output between mechanized and non-mechanized farms, an arithmetic decomposition technique was employed. The goal of this decomposition method is to disaggregate the difference in observed output between the two farm types into its explanatory components, viz. yield, cropping intensity, area and price. Since no attempt has ever been made to examine simultaneously the effects of these contributory components to output growth due to mechanization and to quantify their magnitudes together, this formulation was specifically aimed to bridge this methodological gap.

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[5/] Siegel, S. Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill Kogakusha, Ltd., 1956, pp.184-193.

The general framework of the following decomposition model was formulated as a synthesis of the formulation of Raj Krishna (1974) and Hans Binswanger (1978). It utilizes the output identity defined as:

$$Q = C \; \Sigma A_i Y_i$$

where:

$Q$ - value of output per hectare of operated area

$C$ - cropping intensity defined as the gross cropped area divided by operated area per crop

$A_i$ - weighted proportion of gross cropped area under ith crop

$Y_i$ - yield of crop i in money terms

Comparison of farms was made on the basis of whether land preparation was done using tractor or carabao power. Output generated from the tractor farms is denoted by $Q^1$ and output from the carabao farms is expressed as $Q^o$. The difference in output of the two groups of farms is given by the following equation:

$$Q^1 - Q^o = C^1 \Sigma A_i^1 Y_i^1 - C^o \Sigma A_i^o Y_i^o \quad \text{........(1)}$$

The derivation of the general formula for the decomposition models employs a commonly-used mathematical device, i.e., the addition and substraction of the same terms.

Adding and substracting $C^o \Sigma A_i^1 Y_i^1$ ,

$$Q^1 - Q^o = C^1 \Sigma A_i^1 Y_i^1 - C^o \Sigma A_i^o Y_i^o + C^o \Sigma A_i^1 Y_i^1 - C^o \Sigma A_i^1 Y_i^1 \quad \ldots\ldots\ldots(2)$$

and collecting common terms result in:

$$Q^1 - Q^o = (C^1 - C^o) \Sigma A_i^1 Y_i^1 + C^o(\Sigma A_i^1 Y_i^1 - \Sigma A_i^o Y_i^o) \quad \ldots\ldots\ldots\ldots\ldots(3)$$

Define the quantity $(C^1 - C^o) \Sigma A_i^1 Y_i^1$ as component A and the quantity $C^o(\Sigma A_i^1 Y_i^1 - \Sigma A_i^o Y_i^o)$ as component B. In order to simplify the notations, differences in output, yield, area weight and cropping intensity can now be written in terms of delta ($\Delta$) such that,

$$Q^1 - Q^o = \Delta Q \qquad A^1 - A^o = \Delta A$$

$$C^1 - C^o = \Delta C \qquad Y^1 - Y^o = \Delta Y$$

Working first on component B and expanding it by using Identity I from Appendix I-A leads to:

$$\begin{aligned} \Delta Q &= \Delta C \, \Sigma A_i^1 Y_i^1 + C^o(\Sigma \Delta A_i Y_i^1 + \Sigma A_i^o \Delta Y_i) \\ &= \Delta C \, \Sigma A_i^1 Y_i^1 + C^o \Sigma \Delta A_i Y_i^1 + C^o \Sigma A_i^o \Delta Y_i \quad \ldots\ldots\ldots\ldots (4) \end{aligned}$$

The first term of Equation 4 is the cropping intensity effect, the second term is the area effect[6/] and the third term is the overall yield effect. This formulation is actually the

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[6/] The second term of Equation 4 is actually the cropping pattern effect in the Binswanger model, but since the present model is designed for mono crop (rice) production, it necessarily becomes an area effect.

decomposition model proposed by Binswanger (1979) without the residual term. It was derived to decompose output differences between large and small farms.

So far it has been assumed that all farms face identical prices. Suppose there is reason to believe that farms do not face the same prices so that a price effect might also be important. From Equation 4, the overall yield effect is:

$$C^o \Sigma A_i^o(Y_i^1 - Y_i^0) = C^o \Sigma A_i^o(X_i^1 P_i^1 - X_i^o P_i^o)$$

where:

$Y_i = P_i X_i$

$X_i$ - physical yield of ith crop in kilograms

$P_i$ - price per kilogram of the ith crop

$$\begin{aligned} C^o \Sigma A_i^o(X_i^1 P_i^1 - X_i^o P_i^o) &= C^o \Sigma A_i^o(X_i^1 P_i^1 - X_i^o P_i^o + X_i^1 P_i^o - X_i^1 P_i^0) \\ &= C^0 \Sigma A_i^o X_i^1 (P_i^1 - P_i^o) + C^o \Sigma A_i^o P_i^o (X_i^1 - X_i^o) \\ &= C^o \Sigma A_i^o X_i^1 \Delta P_i + C^o \Sigma A_i^o P_i^o \Delta X_i \end{aligned}$$

The decomposition model which includes the price variable may be written as:

$$\Delta Q = \Delta C \, \Sigma A_i^1 P_i^1 X_i^1 + C^o \Sigma \Delta A_i P_i^1 X_i^1 + C^o \Sigma A_i^o X_i^1 \Delta P_i + C^o \Sigma A_i^o P_i^o \Delta X_i \quad \ldots(5)$$

Equation 5 can be expanded to include interaction terms by employing Identity II of Appendix I-B such that:

$$\Delta Q = \Delta C\Sigma A_i^1P_i^1X_i^1 + C^0(\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0)$$

$$= \Delta C\Sigma A_i^1P_i^1X_i^1 + \Delta C\Sigma A_i^0P_i^0X_i^0 - \Delta C\Sigma A_i^0P_i^0X_i^0 + C^0(\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0)$$

$$= \Delta C\Sigma A_i^0P_i^0X_i^0 + \Delta C(\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0) + C^0(\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0)$$

Using Identity III from Appendix I-C to expand the parenthesized expressions leads to the final decomposition equation:

$$\Delta Q = \Delta C\Sigma A_i^0P_i^0X_i^0 + \Delta C\Big[\Sigma A_i^0P_i^0\Delta X_i + \Sigma\Delta A_iP_i^0\Delta X_i + \Sigma\Delta A_iP_i^0X_i^0 + \Sigma\Delta A_i\Delta P_i\Delta X_i$$
$$+ \Sigma\Delta A_i\Delta P_iX_i^0 + \Sigma A_i^0\Delta P_i\Delta X_i + \Sigma A_i^0\Delta P_iX_i^0\Big] + C^0\Big[\Sigma A_i^0P_i^0\Delta X_i$$
$$+ \Sigma\Delta A_iP_i^0\Delta X_i + \Sigma\Delta A_iP_i^0X_i^0 + \Sigma\Delta A_i\Delta P_i\Delta X_i + \Sigma\Delta A_i\Delta P_iX_i^0$$
$$+ \Sigma A_i^0\Delta P_i\Delta X_i + \Sigma A_i^0\Delta P_iX_i^0\Big]$$

Arranging the terms:

$$\begin{aligned}
\Delta Q = \; & \Delta C\Sigma A_i^0P_i^0X_i^0 && \text{- cropping intensity effect} \\
& + C^0\Sigma A_i^0P_i^0\Delta X_i && \text{- pure yield effect} \\
& + C^0\Sigma\Delta A_iP_i^0X_i^0 && \text{- area effect} \\
& + C^0\Sigma A_i^0\Delta P_iX_i^0 && \text{- price effect} \\
& \left.\begin{aligned} & + \Delta C\Sigma A_i^0P_i^0\Delta X_i \\ & + \Delta C\Sigma\Delta A_iP_i^0X_i^0 \\ & + \Delta C\Sigma A_i^0\Delta P_iX_i^0 \end{aligned}\right\} && \text{first-order interaction terms}
\end{aligned}$$

$$\left.\begin{array}{l}
+ \quad C^o \, \Sigma \, \Delta A_i \Delta P_i X_i^o \\
+ \quad C^o \, \Sigma \, \Delta A_i P_i^o \Delta X_i \\
+ \quad C^o \, \Sigma \, A_i^o \Delta P_i \Delta X_i
\end{array}\right\}$$

$$\left.\begin{array}{l}
+ \quad \Delta C \, \Sigma \, \Delta A_i P_i^o \Delta X_i \\
+ \quad \Delta C \, \Sigma \, \Delta A_i \Delta P_i X_i^o \\
+ \quad \Delta C \, \Sigma \, A_i^o \Delta P_i \Delta X_i \\
+ \quad C^o \, \Sigma \, \Delta A_i \Delta P_i \Delta X_i
\end{array}\right\} \text{ - second-order interaction terms}$$

$$+ \quad \Delta C \, \Sigma \, \Delta A_i \Delta P_i \Delta X_i \qquad \text{ - third-order interaction term}$$

This model is an extension of Binswanger's model without residual. In the present formulation, interaction terms were incorporated and treated as first-order, second-order and third-order interaction effects of the contributory components. These interaction effects indicate the influence of any of the factors over the other that brought about output differences between farm types. The degree of the interaction terms expresses the number of component elements that are allowed to change simultaneously in the model. The first-order interaction terms will refer to the simultaneous effects of the component elements taken two at a time. The second-order interaction terms will mean three components are changing simultaneously and the third-order interaction term reflects the simultaneous effect of all the four components.

To clarify the issue of interaction effects, an example is called for. Take the case of the first-order interaction between cropping pattern and price variables. This can be useful in finding whether the growth in gross cropped area of a particular crop is due to the relative profitability of the crop because of a favorable price in the market or not. This can also be due to a higher productivity level and the second-order interaction between yield, price and cropping pattern would help in understanding this. That is, the relative profitability of the crop brought about by increased productivity and favorable price in the market would change the cropping pattern in its favour. Hence, the interaction of cropping pattern with price and yield can provide an insight into the pattern of crop adjustments towards crops with higher yield or with higher price, and the second-order interaction effect of these three components can shed some light on the allocation of cultivated area to particular crops.

## 3.2 Decomposition Model II

Previous studies (Minhas and Vaidyanathan, 1965), (Sagar, 1977) showed that the most important source of output growth associated with the introduction of new technology is yield. The second part of this methodology outlines another decomposition scheme that will disaggregate the difference in per hectare paddy output into components brought about by technical change (neutral and non-neutral technological change) and change in the levels of inputs used.

The decomposition model involves the use of a production function and is formulated specifically to answer the following questions:

a. is there a difference in the structural form if the production functions derived from mechanized and non-mechanized farms, i.e., are the intercept and slope coefficients for mechanized technology equal to the coefficients of the non-mechanized technology?

b. if there is structural difference, is it due to changes in the efficiency parameter (intercept) of the production function or changes in the output elasticities (slope parameters) of the inputs used, or both?

The framework is a revised model of Bisaliah (1977) employing the use of a Cobb-Douglas model. The production function for mechanized farms is specified as follows:

$$Y_M = A_M L_M^{B_1} F_M^{B_2} C_M^{B_3} P_M^{B_4} U_M \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Similarly, the production function for non-mechanized farms could be specified as follows:

$$Y_B = A_B L_B^{Z_1} F_B^{Z_2} C_B^{Z_3} P_B^{Z_4} U_B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:

Y - yield per hectare of palay in kilograms

L - pre-harvest labor input per hectare measured as total manhours used in planting, care and cultivation of the crop except land preparation. These included activities like seeding of seedbed, pulling of seedlings, transplanting, irrigating, fertilizer application, weeding and applying weedicide and insecticide.

F - total amount of fertilizer used per hectare converted to nitrogen in kilograms (see appendix III)

C - total amount of crop protection used, i.e., pesticide, insecticide, fungicide, herbicide, weedicide and rodenticide valued in pesos per hectare

P[7/] - total amount of machine/animal services used in land preparation measured in man-machine/animal hours per hectare.

A – scale parameter

$B_i$ – output elasticities of inputs for the mechanized farms

$Z_i$ – output elasticities of inputs for the non-mechanized farms

U and E – disturbance terms

where: $E = \log U$

M – mechanized farms

B – non-mechanized farms

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7/ In decomposing the structural differences of the production functions for the mechanized and the non-mechanized farms, the variable P must be made comparable for both farms, since in the case of the mechanized farms, P is measured in terms of man-machine hours, while in the case of non-mechanized farms, P is in terms of man-animal hours. To make them comparable, man-machine hours were converted to equivalent man-animal hours by multipying a proportion which measure the speed of a particular type of tractor, i.e., 2-wheel or 4-wheel, over a carabao in preparing a hectare of land. This was done by comparing the average amount of machine hours needed to plow, harrow and level a hectare of land to the average amount of animal hours.

In the case of 2-wheel tractor farms versus carabao farms, the ratio of the speed of the tractor over the carabao in preparing a hectare of land is 3.3 (see Table 4). For the combination of 2-wheel/4-wheel tractor versus carabao farms, the ratio is 3.4. These values were therefore used to standardize P and hence made them comparable.

The production functions can be transformed into the locarithmic form as follows:

$$\log Y_M = \log A_M + B_1 \log L_M + B_2 \log F_M + B_3 \log C_M + B_4 \log P_M + E_M \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

$$\log Y_B = \log A_B + Z_1 \log L_B + B_2 \log F_B + B_3 \log C_B + B_4 \log P_B + E_B \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4)$$

The structural difference of the two production functions was tested using the Chow's test.[8/] In case the statistical test demonstrates or reveals significant differences between the two sets of coefficients, the decomposition Model II was then employed.

The decomposition model can be derived by taking the difference of the predicted linearized production functions for both mechanized and non-mechanized farms using average values for each variables.

$$\log \bar{Y}_M - \log \bar{Y}_B = (\log \hat{A}_M - \log \hat{A}_B) + (\hat{B}_1 \log \bar{L}_M - \hat{Z}_1 \log \bar{L}_B) + (\hat{B}_2 \log \bar{F}_M - \hat{Z}_2 \log \bar{F}_B) + (\hat{B}_3 \log \bar{C}_M - \hat{Z}_3 \log \bar{C}_B) + (\hat{B}_4 \log \bar{P}_M - \hat{Z}_4 \log \bar{P}_B) + (E_M - E_B) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5)$$

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[8/] Chow, G.C., "Test of Equality Between Sets of Coefficients in Two Linear Regressions," Econometrica, Vol. 28, No. 3. July, 1960, pp. 591-605.

Adding and subtracting some terms to (5) and rearranging them results in:

$$\left[\log Y_M - \log Y_B\right] = \left[\log \hat{A}_M - \log \hat{A}_B\right] + \left[(\hat{B}_1 - \hat{Z}_1) \log \bar{L}_B + (\hat{B}_2 - \hat{Z}_2) \log \bar{F}_B + (\hat{B}_3 - \hat{Z}_3) \log \bar{C}_B + (\hat{B}_4 - \hat{Z}_4) \log \bar{P}_B\right] + \left[\hat{B}_1 (\log \bar{L}_M - \log \bar{L}_B) + \hat{B}_2 (\log \bar{F}_M - \log \bar{F}_B) + \hat{B}_3 (\log \bar{C}_M - \log \bar{C}_B) + \hat{B}_4 (\log \bar{P}_M - \log \bar{P}_B)\right] + \left[E_M - E_B\right] \quad \ldots . (6)$$

Equation (6) could also be written as:

$$\log\left[\frac{\bar{Y}_M}{\bar{Y}_B}\right] = \left[\log \left[\frac{\hat{A}_M}{\hat{A}_B}\right]\right] + \left[(\hat{B}_1 - \hat{Z}_1) \log \bar{L}_B + (\hat{B}_2 - \hat{Z}_2) \log \bar{F}_B + (\hat{B}_3 - \hat{Z}_3) \log \bar{C}_B + (\hat{B}_4 - \hat{Z}_4) \log \bar{P}_B\right] + \left[\hat{B}_1 \log \left[\frac{\bar{L}_M}{\bar{L}_B}\right] + \hat{B}_2 \log \left[\frac{\bar{F}_M}{\bar{F}_B}\right] + \hat{B}_3 \log \left[\frac{\bar{C}_M}{\bar{C}_B}\right] \hat{B}_4 \log \left[\frac{\bar{P}_M}{\bar{P}_B}\right]\right] + \left[E_M - E_B\right] \quad \ldots \ldots \ldots . (7)$$

Using this decomposition scheme, the per hectare output differences between mechanized and non-mechanized farms can be decomposed into three components:

a. neutral technological change (i.e., shift in the intercept of the production function)

b. non-neutral technological change (i.e., shift in the slope parameters of the production function)

c. change in the volume of inputs used (i.e., labor, fertilizer, crop protection and capital services)

The decomposition Model II approximates a measure of the percentage change in output (Appendix II) due to mechanization holding all other factors like irrigation and seed varieties constant. Equation (7) involves the disaggregation of the natural logarithm of the ratio of output produced from mechanized and non-mechanized farms. The first bracketed expression on the right hand side, the natural logarithm of the ratio of the intercept terms, measures the percentage change in output due to neutral technological change. The second bracketed expression, the sum of the arithmetic changes of slope parameters each weighted by the logarithm of the volume of the particular input used, measures the percentage change in output due to non-neutral technological change. The third bracketed expression, the sum of the logarithms of the ratio of each input used under mechanized and non-mechanized farms, each weighted by the output elasticity of that input, measures the percentage change in output due to changes in labor, fertilizer, crop protection and capital services used. The fourth bracketed expression is simply the measure of differences in error terms.

The decomposition models formulated in this section attempt to assess the possible impact of mechanization on small rice farms. They were designed to present a fairly complete picture of the sources of output growth that can be attributed to mechanization.

Drawbacks of these decomposition techniques are expected to arise during the process of analysis. In the case of the first model, i.e., the simple arithmetic decomposition scheme, one of the limitations that can easily be pointed out is that although it involves heavy (but simple) computational work, it is wasteful of information because it does not use all the available data due to aggregation. Another is that, it is considered as an ad hoc method for analyzing the impact of mechanization on production since no rigorous methodological framework was involved in its formulation. It is purely an accounting method. This does not, however, mean that the results are barren of significant interpretation. The manner in which output growth was decomposed in the models are expected to bring out the important factor(s) that are affected by mechanization. The technique attempts to address the question of the source of the major differences in output between the mechanized and non-mechanized farms. This provides direction in evaluating the impacts of mechanization on yield, cropping intensity, cropping pattern and price, if they exist. It leads one to ask precisely why such an effect arises and hence, the possible source of the effect. Is mechanization responsible for that effect or is it simply spurious?

The second model, i.e., the decomposition scheme using the production function framework, is of course subject to all the possible limitations of a Cobb-Douglas formulation such as least-squares bias, multicollinearity and specification errors. The scheme, however, tries to answer questions raised from the first decomposition model. It specifically presents the component elements that are causal to the possible yield effects of mechanization.

### 3.3 Source of Data

The data used in this study was taken from a cross-country survey conducted for "The Consequences of Small Rice Farm Mechanization Project in Asia" by the International Rice Research Institute which began in 1978 in Indonesia, Philippines and Thailand. The primary objective of the survey was to determine the impact of small rice farm mechanization on production, income and rural employment. The data gathering component of the survey consisted of two parts, a series of cross-sectional surveys (i.e., 1979 wet season, 1979-80 dry season and 1980 wet season) and a complementary daily record keeping system on selected farms.

## 3.4 Sampling Procedures[9/]

A household census was administered at the beginning of the study to identify the farm operators and landless field laborers in each barrio. Data collected from the census was used primarily in selecting the samples needed for the study.

Two municipalities which were primary rice producing areas were purposively selected. Selection was based on the survey's primary stratification criteria which are: the type and extent of irrigation available and the degree of mechanization in land preparation.

To select the sample households, stratified random sampling was employed. The stratification based on the type of irrigation and power used for primary tillage is as follows:

1. rainfed - animal power
2. rainfed - 2-wheel tractor
3. rainfed - 4-wheel tractor
4. irrigated, one cropping season - animal power
5. irrigated, one cropping season - 2-wheel tractor
6. irrigated, one cropping season - 4-wheel tractor
7. irrigated, two or more cropping season - animal power

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[9/] Moran P. and Unson D. "Farm Survey and Recordkeeping Procedures for the Consequences of Small Rice Farm Mechanization Project: Operation Handbook" IRRI/USAID, May 1980.

8. irrigated, two or more cropping season - 2-wheel tractor
9. irrigated, two or more cropping season - 4-wheel tractor
10. landless field laborers

The stratification unit used in the farm households was the parcel and not the total farmholding. Parcels located outside the sample barrios and those that totalled to more than 10 hectares were excluded. The latter exclusion was due to its size category which is outside the definition of small farm. In the case of farmers with more than one parcel, stratification was based on the parcel with the largest area planted to rice. If the largest parcel was located outside the sample barrio, the largest among parcels within the barrio was chosen to characterize the total farmholding.

After all the rice farm households and field labor households had been placed in respective stratification cells, 40 households were randomly drawn from each of the first 9 strata, with the last 5 households serving as substitutes or replacements in case of dropouts. In the case of the last strata, the landless labor classification, 60 samples were drawn, with the last 10 serving as replacements. In the case of strata with census populations having less than the required number of observations, a total enumeration of that classification was taken.

# CHAPTER IV

# STUDY AREA AND CHARACTERISTICS OF THE SAMPLE FARMS

## 4.1 Study Area

The cross-sectional farm surveys were conducted in Nueva Ecija for the wet and dry seasons of the years 1979, 1980 and 1981 in two municipalities, i.e., Cabanatuan and Guimba, each having four sample barrios. In Cabanatuan, the following barrios were included: San Isidro, Lagare, Kalikid Sur and Caalibangbangan. In Guimba are Galvan, Narvacan I, San Andres and Bunol (Table 1).

In this study, farms were classified according to the type of power used in land preparation which included activities such as plowing, harrowing and levelling. Non-mechanized farms were those samples that used carabao alone for land preparation, while the mechanized farms were those that used either 2-wheel tractor, 4-wheel tractor or both for land preparation.

There were 368 sample farms in the survey. One hundred thirty one of these sample farms were classified as non-mechanized, 86 were purely mechanized and 105 used tractor and carabao power combinations. Under the mechanized farms, one was rainfed and 85 were irrigated. Under non-mechanized farms, 48 farms

Table 1. Distribution of sample farms by municipality and barrio, Nueva Ecija, Philippines, 1979

| MUNICIPALITY/BARRIO | NUMBER OF SAMPLE HOUSEHOLDS |
|---|---|
| Cabanatuan | |
| San Isidro | 49 |
| Lagare | 47 |
| Kalikid Sur | 24 |
| Caalibangbangan | 76 |
| Guimba | |
| Galvan | 35 |
| Narvacan I | 39 |
| San Andres | 45 |
| Bunol | 53 |

were irrigated and 83 were rainfed (Table 2). The remaining 46 farmer respondents were landless field workers.

### 4.2 Characteristics of Sample Farms

The samples selected for inclusion in the present study were those farms that were irrigated and users of modern rice varieties. It was not possible to pick samples from the rainfed farms since none of the respondents used tractor(s) for land preparation (Table 2). There were those that used tractor(s), however, they are in combination with carabao power in preparing the field.

Demographic characteristics of sample farms, i.e., age, number of years in school and experience in farming, as shown in Table 3, did not differ much between farm types.

In terms of farm area (Table 4), 2-wheel tractor farms were on the average, 1.22 times larger than carabao farms and 1.5 times larger than the 2-wheel/4-wheel-tractor combination farms.

Cropping intensity was lowest for the carabao farms. Both mechanized farm types had cropping intensities of 1.5 higher than the carabao farms.

Yield per hectare was more than 1.5 times higher in the mechanized farms than the non-mechanized farms.

Pre-harvest labor excluding land preparation did not vary much between the farm types. On the other hand, post-production

Table 2. Distribution of sample farms by type of power used in land preparation and irrigation, Nueva Ecija, Philippines, Wet Season, 1979

| POWER | IRRIGATION | | | |
|---|---|---|---|---|
| | Gravity | Deep well | Rainfed | Total |
| Carabao | 11 | 37 | 83 | 131 |
| 2-wheel tractor | 62 | 1 | 1 | 64 |
| 4-wheel tractor | 2 | - | - | 2 |
| 2-wheel/4-wheel tractor combination | 20 | - | - | 20 |
| 2-wheel/carabao | 27 | 3 | 26 | 56 |
| 4-wheel/carabao | 9 | 10 | 12 | 31 |
| 2-wheel/4-wheel/carabao | 15 | 1 | 2 | 18 |
| Total | 146 | 52 | 124 | 322 |

Table 3. Demographic characteristic of sample farms by type of mechanization, Nueva Ecija, Philippines, Wet Season, 1979

| CHARACTERISTICS | CARABAO FARMS | 2-WHEEL TRACTOR FARMS | 2-4 WHEEL TRACTOR FARMS |
|---|---|---|---|
| Number of households | 46 | 62 | 20 |
| Average age of the household head (years) | 44 | 49 | 46 |
| Average education of household head (years) | 4 | 4 | 4 |
| Average experience in farming of household head (years) | 19 | 22 | 18 |

Table 4. Characteristics of sample farms by type of mechanization, Nueva Ecija, Philippines, Wet Season, 1979

| OPERATION | CARABAO FARMS | 2-WHEEL TRACTOR FARMS | 2-4 WHEEL TRACTOR FARMS |
|---|---|---|---|
| Area (hectares) | 1.95 | 2.39 | 1.59 |
| Production (kilograms) | 5089.50 | 9591.93 | 7710.85 |
| Yield per hectare (kgs.) | 2610.00 | 4013.36 | 3702.54 |
| Price of paddy (₱/kg.) | 1.06 | 1.17 | 1.05 |
| Total pre-harvest labor (m-hrs/ha.) | 247.02 | 223.28 | 259.61 |
| Total post-production labor (m-hrs/ha.) | 244.41 | 207.34 | 222.58 |
| Total land preparation hours (man-machine or man-animal hours/hectare) | 96.79 | 29.52 | 28.10 |
| Level of fertilizer (kg.N/ha) | 40.13 | 57.98 | 87.43 |
| Value of crop protection (₱/ha) | 96.69 | 186.44 | 145.52 |
| Loan for seasonal farm expense per hectare | 1023.44 | 1215.35 | 902.77 |
| Long term loan for agricultural investment per hectare | 1954.87 | 2484.56 | 3081.76 |
| Cropping intensity * | 1.36 | 1.92 | 1.97 |

$$^{*}\text{Cropping intensity} = \frac{\text{gross cropped area in a given crop year}}{\text{Operated area per crop}} \times 100$$

- computed for wet and dry season data

labor which includes harvesting, threshing and winnowing, was highest in the carabao farms followed by 2-wheel/4-wheel-tractor combination and 2-wheel tractor farms. This higher post-production labor of the carabao farms over the tractor farms was due to the wide use of threshers by the tractor farms instead of manually threshing the harvest.

Land preparation hours, however, showed a sharp drop from the average 96.79 man-animal hours of the carabao farms to 29.52 and 28.10 man-machine hours of the mechanized farms.

Fertilizer use and crop protection, i.e., use of insecticides, weedicides and rodenticides were consistently higher on the mechanized than the non-mechanized farms.

Short-term loan for seasonal farm expense per hectare was highest in the 2-wheel tractor farms followed by carabao and 2-wheel/4-wheel tractor combination farms. Long-term loans, however, used for agricultural investment, i.e., purchase of farm machines, carabao and irrigation pumps, was higher on both mechanized than the non-mechanized farms.

CHAPTER V

# RESULTS AND DISCUSSION

This Chapter presents the major results of the study. Decomposition Models I and II were employed to evaluate whether mechanization increases output or not. The observed output differences between farms "with and without" mechanization was disaggregated into the factors that brought about such differences.

## 5.1 Results of the Arithmetic Decomposition Scheme

Production variables of mechanized and non-mechanized farms were investigated and tested for differences using the Kruskal-Wallis one-way analysis of variance by ranks. Table 5 shows that area for the dry season, average area between wet and dry seasons, yield for the wet season, average yield for the wet and dry seasons, price for the wet season, average price, fertilizer use, level of crop protection and land preparation hours were all significantly different between 2-wheel tractor and carabao farms. In the case of the 2-wheel/4-wheel tractor combination versus carabao farms, the following variables, namely, area for dry season, yield for wet season, average yield, price for dry season, fertilizer use, level of crop protection, labor hours and land preparation hours showed

Table 5. Test for differences of variables between tractor and carabao farms using the Kruskal-Wallis one-way analysis of variance by ranks

| VARIABLES | VALUE OF H*** 2-wheel tractor farms vs. carabao farms | 2-wheel/4-wheel tractor farms vs. carabao farms |
|---|---|---|
| Area (wet season) | $-5.81^{n.s.}$ | $0.63^{n.s.}$ |
| Area (dry season) | 30.58** | 6.93** |
| Average area | 14.55** | $0.14^{n.s.}$ |
| Yield (wet season) | 18.57** | 7.68** |
| Yield (dry season) | $3.31^{n.s.}$ | $1.68^{n.s.}$ |
| Average yield | 10.08** | 4.44* |
| Price (wet season) | 9.88** | $0.41^{n.s.}$ |
| Price (dry season) | $0.43^{n.s.}$ | 6.07* |
| Average price | 4.30* | $2.62^{n.s.}$ |
| Fertilizer use | 5.61* | 40.91** |
| Level of crop protection | 13.99** | 5.83* |
| Labor hours | $-5.65^{n.s.}$ | 32.88** |
| Land preparation hours | 32.03** | 36.33** |

n.s. - not significant

* - significant at 5% level

** - significant at 1% level

*** - see Appendix II

signicant statistical differences. These results provided a good reason to decompose the possible production effects of mechanization.

Decomposition analysis was carried out for 2-wheel tractor and 2-wheel/4-wheel-tractor combination against carabao farms. The results of the analyses are presented in Tables 7 to 14.

Decomposition of output differences between farms using 2-wheel tractor and carabao farms employing Binswanger's model without interaction terms (Table 7) showed that the component which contributed the largest percentage to the output difference is the cropping intensity effect (47.59%) followed by the overall yield effect (39.23%) and area effect (13.18%). Breaking out a price effect from the overall yield effect (Table 8) showed that 7.83% of the difference in output is due to the difference in prices received by the two farm types. This left a pure yield effect of 31.40%.

Using the version with interaction terms showed the same overall yield effect (39.23%). Cropping intensity effect went down to 26.01% (Table 9). Breaking out a price effect resulted in a percentage contribution of price of 4.96% and pure yield effect of 31.40% (Table 10). The area effect was hardly changed registering 11.22%. This is quite expected since the decision of farmers to increase area devoted to

Table 6. Means of variables used in applying the arithmetic decomposition analysis, wet season, 1979 and dry season, 1980

| COMPONENT ELEMENTS | FARM TYPES | | |
|---|---|---|---|
| | Bullock Farms | 2-wheel tractor farms | 2-4 wheel tractor farms |
| Number of observations | 42 | 52 | 20 |
| Cropping intensity | 1.36 | 1.92 | 1.97 |
| Area (expressed in weights) | | | |
| wet season | 1.44 | 1.24 | 0.80 |
| dry season | 0.72 | 1.20 | 0.81 |
| Physical yield (kgs.) | | | |
| wet season | 2587.22 | 4105.72 | 3702.54 |
| dry season | 3058.17 | 4154.02 | 4380.73 |
| Price (₱/kg.) | | | |
| wet season | 1.05 | 1.18 | 1.05 |
| dry season | 1.15 | 1.16 | 1.08 |

Table 7. Decomposition analysis (without interaction terms) of output differences between 2-wheel tractor and carabao farms

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| overall yield effect | 5442.50 | 39.23 |
| area effect | 1827.85 | 13.18 |
| cropping intensity effect | 6602.34 | 47.59 |
| Total | 13872.70 | 100.00 |

Table 8. Decomposition analysis (without interaction terms) of output differences between 2-wheel tractor and carabao farms with price variable

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| price effect | 1085.96 | 7.83 |
| pure yield effect | 4356.54 | 31.40 |
| area effect | 1827.85 | 13.18 |
| cropping intensity effect | 6602.34 | 47.59 |
| Total | 13872.70 | 100.00 |

Table 9. Decomposition analysis (with interaction terms) of output differences between 2-wheel tractor and carabao farms

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| A. Individual effects | | |
| overall yield effect | 5442.50 | 39.23 |
| Area effect | 1556.92 | 11.22 |
| Cropping intensity | 3608.66 | 26.01 |
| B. First-order interaction effects | | |
| yield and area | 270.93 | 1.95 |
| cropping intensity and area | 641.08 | 4.62 |
| cropping intensity and yield | 2241.03 | 16.15 |
| C. Second-order interaction effect | | |
| cropping intensity, area and yield | 111.56 | 0.82 |
| Total | 13872.70 | 100.00 |

Table 10. Decomposition analysis (with interaction terms) of output differences between 2-wheel tractor and carabao farms with price variable

| EFFECT | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| A. Individual effects | | |
| pure yield effect | 4356.54 | 31.40 |
| area effect | 1556.92 | 11.22 |
| cropping intensity effect | 3608.66 | 26.01 |
| price effect | 688.63 | 4.96 |
| B. First-order interaction effects | | |
| yield and price | 397.33 | 2.86 |
| area and price | -71.52 | -0.52 |
| area and yield | 388.99 | 2.80 |
| cropping intensity and yield | 1793.87 | 12.93 |
| cropping intensity and price | 283.55 | 2.04 |
| cropping intensity and area | 641.08 | 4.62 |
| C. Second-order interaction effects | | |
| cropping intensity, price and area | -29.45 | -0.21 |

Table 10. (continued)

| | | |
|---|---|---|
| cropping intensity, price and yield | 163.61 | 1.18 |
| cropping intensity, yield and area | 160.17 | 1.15 |
| price, yield and area | -46.54 | -0.34 |
| D. Third-order interaction effect | | |
| cropping intensity, price, yield and area | -19.16 | -0.10 |
| Total | 13872.70 | 100.00 |

rice production is not likely to be influenced by factors of productivity like yield and cropping intensity. It is controlled by other factors that are not incorporated in the model, such as increases in demand, government investment in land reclamation, irrigation, credit and extension services, or private investment due to relative profitability as a result of better returns even at increased cost of land rent and acquisition.

Since the area effect is the same for both models, i. e., with and without interaction terms, then the interaction effects could only be expected to come out from the simultaneous change in cropping intensity and yield.

From Table 9, the largest interaction effect resulted from cropping intensity and yield (16.15%). Interaction effects of area with yield and with cropping intensity were relatively small, 1.95% and 4.62% respectively.

Breaking out interaction effects of price with yield and cropping intensity showed quantitatively small percentage contribution (1.86% and 2.04% respectively). The interaction effect of cropping intensity with physical yield decreased to 12.93%, however, it is still the largest percentage contribution in the set of first order interaction effects. The second-order and third order interation effects of the component elements showed very little percentage contribution

(Table 10).

In the case of the decomposition of output between 2-wheel/ 4-wheel-tractor combination and carabao farms, the effects of the component elements showed exactly the same pattern as the 2-wheel tractor versus carabao farms. Using the model without interaction terms (Table 11) showed that cropping intensity effect gave the highest percentage contribution (86.95%) followed by the overall yield effect (71.59%) and area effect (-58.54%). Breaking out a price effect (Table 12) resulted to 6.16%. The negative sign suggests that the average value of a component for 2-wheel/4-wheel-tractor combination farms is lower than the average value for carabao farms.

Employing the model with interaction terms gave the same overall yield effect of 71.59% (Table 13). Cropping intensity and area effects went down slightly to 81.07% and -40.40% respectively. With respect to price effect, it decreased to -4.31% (Table 14).

Among the first-order interaction effects, the interaction between yield and cropping intensity registered the highest percentage contribution both in the model without and with price variable (32.22% and 34.99% respectively). The second-order and third-order interaction effects gave very low percentage contributions.

Table 11. Decomposition analysis (without interaction terms) of output differences between 2-wheel/4-wheel-tractor combination and carabao farms

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| yield effect | 3482.50 | 71.59 |
| area effect | -2847.48 | -58.54 |
| cropping intensity effect | 4229.51 | 86.95 |
| Total | 4864.53 | 100.00 |

Table 12. Decomposition analysis (without interaction terms) of output differences between 2-wheel/4-wheel-tractor combination and carabao farms with price variable

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| yield effect | 3782.76 | 77.76 |
| area effect | -2847.47 | -58.54 |
| cropping intensity effect | 4229.51 | 86.94 |
| price effect | -300.27 | -6.16 |
| Total | 4864.53 | 100.00 |

Table 13. Decomposition analysis (with interaction terms) of output differences between 2-wheel/4-wheel-tractor combination and carabao farms

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| Sources of output differences | | |
| A. Individual effects | | |
| yield effect | 3482.50 | 71.59 |
| area effect | -1965.35 | -40.40 |
| cropping intensity effect | 3943.75 | 81.07 |
| B. First-order interaction effects | | |
| yield and area | -882.13 | -18.13 |
| yield and cropping intensity | 1567.12 | 32.22 |
| area and cropping intensity | -884.41 | -18.18 |
| C. Second-order interaction effect | | |
| cropping intensity, area and yield | -396.96 | -8.17 |
| Total | 4864.53 | 100.00 |

Table 14. Decomposition analysis (with interaction terms) of output differences between 2-wheel/4-wheel-tractor combination and carabao farms with price variable

| EFFECTS | ABSOLUTE CHANGE | PERCENTAGE SHARE |
|---|---|---|
| **Sources of output differences** | | |
| **A. Individual effects** | | |
| yield effect | 3782.76 | 77.76 |
| area effect | -1965.35 | -40.40 |
| cropping intensity effect | 3943.75 | 81.07 |
| price effect | -209.62 | -4.31 |
| B. First-order interaction effects | | |
| yield and price | -90.65 | -1.86 |
| area and price | -24.75 | -0.51 |
| area and yield | -846.68 | -17.40 |
| cropping intensity and area | -884.41 | -18.18 |
| cropping intensity and yield | 1702.24 | 34.99 |
| cropping intensity and price | -94.33 | -1.94 |
| C. Second-order interaction effects | | |
| cropping intensity, price and area | -11.14 | -0.23 |
| cropping intensity, price and yield | -40.79 | -0.84 |

Table 14 (continued)

| | | |
|---|---|---|
| cropping intensity, yield and area | -381.00 | -7.83 |
| price, yield and area | -10.70 | -0.22 |
| D. Third-order interaction effect | | |
| yield, price, area and cropping intensity | -4.82 | -0.10 |
| Total | 4864.53 | 100.00 |

These decomposition analyses showed that the most important factors explaining output differences between mechanized and non-mechanized farms were cropping intesity and yield. The two other factors, area and price bear little significance in bringing about productivity differences. These results, therefore, lead to the identification of variables that are possibly affected by mechanization.

Cropping intensity, as the major component that explained differences in output between mechanized and non-mechanized farms was further investigated. Table 15 summarizes the cropping intensities of the sample farms by type of irrigation and source of power for land preparation. It shows that farms using dam or gravity irrigation have consistently higher cropping intensities than rainfed or deep wells. With respect to each of the irrigation categories, farms were grouped according to whether they are tractor farms, carabao farms or combination of carabao and tractor farms. Cropping intensities of each farm type under each irrigation category were compared. The comparison showed that tractor farms and tractor/carabao combination farms have higher cropping intensities than the carabao farms by 17.4% and 19.9% respectively.

Under deep weel irrigation, the cropping intensity of the carabao/tractor combination was higher than carabao farms by 8.4%. For rainfed farms, cropping intensities of the carabao

**Table 15. Cropping intensity of sample farms by type of power used in land preparation and irrigation, wet season, 1979 and dry season, 1980**

| POWER | IRRIGATION | | |
|---|---|---|---|
| | Gravity | Deep well | Rainfed |
| Carabao farms | 161% | 119% | 103% |
| Tractor farms | 189% | - | - |
| Tractor-Carabao combination | 193% | 129% | 101% |

- no sample

farms and tractor combination farms showed no difference. This is of course expected since rainfed farms are constrained by water availability in the dry season.

These results showed that irrigation was a major factor that affect cropping intensity but some variation did occur when type of irrigation was held constant for the different farm types by degree of mechanization.

Table 16 shows a much disaggregated sample farms by degree of mechanization. Again, under gravity irrigation, tractor farms and tractor/carabao combination farms have consistently higher cropping intensities than the carabao farms. For deep well and rainfed farms, little difference was observed in the cropping intensities of all farm groups by type of mechanization.

These results showed that under no water-constraint condition, farmers still vary in their decisions whether to plant during the second season. In this analysis, mechanization appears to be a factor that potentially increases cropping intensity. However, full credit could not be placed solely on mechanization for the apparent differences in cropping intensities. One striking confounding factor in this respect is that tractor farms are often either better endowed with capital or have better access to credit markets which enable the farmers

Table 16. Cropping intensity of sample farms by type of power used in land preparation and irrigation, wet season 1979 and dry season 1980

| POWER | IRRIGATION | | |
|---|---|---|---|
| | Gravity | Deep well | Rainfed |
| Carabao farms | 161% | 119% | 103% |
| 2-wheel tractor farms | 192% | * | * |
| 4-wheel tractor farms | ** | - | - |
| 2-wheel/4-wheel tractor combination | 197% | - | - |
| 2-wheel/carabao combination | 195% | * | 100% |
| 4-wheel/carabao combination | * | 115% | 101% |
| 2-wheel/4-wheel/carabao combination | 175% | * | ** |

- no sample

* only one sample

** only two samples

to buy the necessary inputs hence afford a second crop (refer to Table 3). This confounding factor, of course, magnifies the cropping intensity effect of mechanization.

## 5.2 Results of the Decomposition Scheme Using the Production Function Framework

Since the second largest component explaining differences in output between mechanized and non-mechanized farms is yield, another decomposition technique using the Cobb-Doubles production function was employed. This scheme disaggregated differences in per hectare paddy output into components brought about by technical change (neutral and non-neutral technological change) and changes in the levels of inputs used.

Cobb-Douglas production functions were fitted for the mechanized and non-mechanized farms. The generated coefficients of the production functions for the three farm types are presented in the following Tables 17, 18 and 19.

The coefficients of the per hectare production functions for both mechanized and the non-mechanized farms showed consistent results with respect to expected signs, though not all variables turned out to be significant. When variable area was incorporated in the model, some of the generated coefficients gave negative signs(Table 18 and 19). This is due to the high multicollinearity of area with the other four variables.

Table 17. Estimated coefficients of the Cobb-Douglas production function for the 2-wheel tractor farms

| INDEPENDENT VARIABLES | DEPENDENT VARIABLES | |
|---|---|---|
| | Total output | Yield/hectare |
| Intercept | 5.65** | 5.16** |
| Power | 0.14<br>(0.1610) | 0.20* |
| Fertilizer use | 0.41** | 0.44** |
| Labor | 0.08<br>(0.2267) | 0.10<br>(0.1467) |
| Crop protection | 0.014<br>(0.8422) | 0.01<br>(0.8836) |
| Area | 0.23* | - |
| $R^2$ | 0.68 | 0.65 |
| N | 62 | 62 |

Figure in parentheses are probabilities of $|T|$ > 't' statistic

* significant at 5% level

** significant at 1% level

Table 18. Estimated coefficients of the Cobb-Douglas production function for the carabao farms

| INDEPENDENT VARIABLES | DEPENDENT VARIABLES | |
|---|---|---|
| | Total output | Yield/Hectare |
| Intercept | 7.37** | 6.4** |
| Power | -0.08<br>(0.4505) | 0.02<br>(0.8702) |
| Fertilizer use | -0.10<br>(0.4270) | 0.034<br>(0.8064) |
| Labor | -0.05<br>(0.6076) | 0.005<br>(0.9622) |
| Crop protection | 0.38** | 0.34** |
| Area | 0.62** | - |
| $R^2$ | 0.78 | 0.33 |
| N | 46 | 46 |

Figures in parentheses are probabilities of $|T|>'t'$ statistic.

* significant at 5% level.

** significant at 1% level.

Table 19. Estimated coefficients of the Cobb-Douglas production function for the 2-wheel/4-wheel tractor combination farms

| INDEPENDENT VARIABLES | DEPENDENT VARIABLES | |
|---|---|---|
| | Total output | Yield/Hectare |
| Intercept | 9.27** | 8.14** |
| Power | -0.23 (0.6458) | 0.028 (0.9423) |
| Fertilizer use | 0.09 (0.8489) | 0.18 (0.6659) |
| Labor | 0.11 (0.7919) | 0.14 (0.7318) |
| Crop protection | -0.18 (0.6207) | 0.27* |
| Area | 0.38* | - |
| $R^2$ | 0.1806 | 0.05 |
| N | 20 | 20 |

Figures in parentheses are probabilities of $|T| > 't'$ statistic

* significant at 5% level

** significant at 1% level

Among the indenpendent variables for mechanized farms, fertilizer use, capital services and crop protection showed significant coefficients while in the case of the non-mechanized farms, only crop protection turned out to be significant (Table 17, 18 and 19).

The production elasticity for labor, although non-significant in all three production functions, was higher in the mechanized farms than the non-mechanized farms.

Fertilizer use had the highest production elasticity for the 2-wheel tractor farms. Non-mechanized farms had the lowest production elasticity for fertilizer use but it had the highest for crop protection.

In the case of power variable, mechanized farms showed higher production elasticities than the non-mechanized farms.

Area showed a positive production elasticity for all three farm types. This is quite contrary to the common inverse relationship of farm size and productivity. However, since the size of the farms used in this study were all small, ranging from 0.5 to 4 hectares, the fitted production functions may not have captured the scale effect.

The structural difference of the production functions derived from the 2-wheel tractor, 2-wheel/4-wheel-tractor combination and carabao farms were tested during Chow's test (Appendix IV). The test revealed significant differences between the 2-wheel tractor and carabao farms, but not between the 2-wheel/4-wheel-tractor combination and carabao farms. This could be due to the very limited sample size used in fitting the production function for the 2-wheel/4-wheel -tractor combination such that the true production relations of inputs to outputs was not captured.

The structural difference between the two production functions, i.e., production functions for the 2-wheel tractor farms and carabao farms was further tested using the dummy variable approach [10/] to search for the source of the structural difference. Was it due to shift in the intercept term or to the shift in the slope coefficients, or both? The dummy variable test showed that there is no significant difference between the two intercept terms. The only variables that showed significant slope dummies were fertilizer and crop protection (Table 20). This means that the only source of structural difference between the 2-wheel tractor farms and carabao farms were the shifts in the slope coefficients of these variables.

With this information in hand, a decomposition scheme employing the use of production function framework was used.

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[10/] Gujarati, D. "Use of Dummy Variables in Testing for Equality Between Sets of Coefficients in Two Linear Regressions: A Note" The American Statistician, Feb. 1970, pp. 50-52

Table 20. Test for structural differences in the production functions for 2-wheel tractor farms and farms using the dummy variable approach

| INDEPENDENT VARIABLES | DEPENDENT VARIABLE (Yield per hectare) |
|---|---|
| Intercept | 5.39** |
| Intercept dummy | 1.01<br>(0.1460) |
| Power | 0.20* |
| Fertilizer | 0.44** |
| Labor | 0.10<br>(0.1531) |
| Crop protection | 0.01<br>(0.8859) |
| Slope dummy for power | -0.18<br>(0.1901) |
| Slope dummy for fertilizer | -0.406** |
| Slope dummy for labor | -0.095<br>(0.4426) |
| Slope dummy for crop protection | 0.33** |
| N | 96 |
| $R^2$ | 0.64 |

Figures in parentheses are probabilities of $|T| >$ 't' statistic.

* significant at 5% level.

** significant at 1% level.

Using Equation 7 of decomposition model II and utilizing the generated production coefficients (Table 17 and 18) and average input levels (Table 21), total changes in per hectare yield differences between 2-wheel tractor farms and carabao farms were decomposed into factors brought about by technical change and changes in the levels of inputs used. The results showed that the percentage contribution of technical change was 48.71% (Table 22).

Technical change affects output by shifting either the intercept or the slope coefficients or both. Disaggregating technical change into neutral and non-neutral technical effects indicates a -9.35% contribution from the shift in the scale parameter and a 58.06% contribution of the shift in the slope parameters.

The contribution of the neutral technical change was shown to be negative which means yield is lower for the mechanized farms when low levels of inputs are used and higher yield are achieved only when inputs are used in sufficient amounts.

The contribution of non-neutral technical change was estimated to be 58.06%. This means that production on the mechanized farms was higher than mechanized farms because of the differences in the allocation of resources to the different types of inputs used. Non-neutral technical change was shown to be positive,

Table 21. Means of variables used in applying the decomposition analysis using the production function framework, wet season, 1979

| VARIABLE | FARM TYPES | |
| --- | --- | --- |
| | Carabao farms | 2-wheel tractor farms |
| Number of observations | 46 | 62 |
| Yield (kg/ha) | 2610.00 | 4013.36 |
| Area (ha) | 1.95 | 2.39 |
| Labor (m-hrs) | 247.02 | 223.28 |
| Power (m-animal/machine hrs/ha) | 96.79 | 70.56 |
| Fertilizer (kg N/ha) | 40.13 | 57.98 |
| Crop protection (₱/ha) | 96.69 | 186.44 |

Table 22. Decomposition analysis of per hectare yield differences between 2-wheel tractor and carabao farms

| COMPONENT | PERCENTAGE SHARE |
|---|---|
| Sources of yield differences | |
| A. Technical change | |
| Neutral technical change | -9.35 |
| Non-neutral technical change | 58.06 |
| Total due to technical change | 48.71 |
| B. Change in inputs | |
| Power | -2.74 |
| Fertilizer | 7.03 |
| Labor | -0.44 |
| Crop protection | 0.28 |
| Total due to input difference | 4.13 |
| Total due to all sources | 52.84 |

indicating a higher contribution of inputs to yield for the mechanized farms.

Total change in yield due to differences in the use of inputs was estimated to be 4.13%. The highest contributor was fertilizer which amounted to 7.03%, followed by capital services with 2.74% share. Post-tillage labor and crop protection registered a minimal percentage contribution of 0.44 and 0.28 per cent respectively.

This decomposition analysis showed that the major source of the structural difference between the 2-wheel tractor and the carabao farms was brought about by non-neutral technical change, i.e., the shift in the slope coefficients. That means 58.06% of the yield differences between 2-wheel tractor and carabao farms was due to the difference in the response of yield to the level of inputs used. Computing for each term of this component showed that the difference in the slope coefficients of labor for the two farms accounted for 22.7%. The difference in fertilizer's coefficients amounted to 65.1% for power, it is 35.77% and crop protection, -65.5%. This shows that the major source of the structural difference in the production functions is due to the difference in the response of yield to fertilizer and crop protection of the two farms.

# CHAPTER VI

## SUMMARY AND CONCLUSION

The main objective of this study was a quantitative assessment of the impact of mechanization on small-scale rice production. It aimed to isolate the sources of output differences between mechanized and non-mechanized farms. To evaluate production effects of mechanization, decomposition analyses were used.

The first model tried was an arithmetic decomposition scheme which disaggregated the output differences between the mechanized and non-mechanized farms into the following component elements:

a. pure yield component

b. price component

c. area component

d. cropping intensity component

e. interactions of these four components

The results of the analysis showed that the most important factors accounting for output differences between the mechanized and non-mechanized farms were cropping intensity and yield.

Mechanization may increase cropping intensity since it allows for faster completion of land preparation hence reducing the turn-around time between crops. The results of the arithmetic decomposition analysis seemed to support this thesis. Further investigation of the cropping intensity effect of mechanziation showed that although irrigation played a major role in the cropping intensity differences of the sample farms, some variation did occur when type of irrigation was held constant for each of the different farm types classified by degree of mechanization. However, since the farmer's decision to plant a second crop is based not only on water availability but also on liquidity, mechanization, therefore, could not be held fully responsible for the apparent differences in cropping intensities on the sample farms.

Yield, on the other hand, presented a more complicated effect, since it is affected by factors not present in the model. To investigate further this yield effect of mechanization, another decomposition technique was employed, using a production function framework. The model decomposed total yield differences between mechanized and non-mechanized farms into:

a. technical change component

b. changes in input used component

The results of the analysis showed that the major source of yield difference between the 2-wheel tractor farms and the carabao farms was brought about by non-neutral technical change, i.e., shifts in the slope coefficients of the production functions, or a difference in the allocation of resources for the two farm types.

These results, taken together, showed that mechanization does increase output, although not impressive, by increasing cropping intensity and yield. Confounding factors such as irrigation, availability of capital for cash inputs like fertilizers and crop protection; access to credit markets and heterogeneity of managerial quality among sample farms played an implicit role that exaggerated the yield and cropping intensity effects of mechanization.

The problem of "trade-offs" between increasing production and increasing employment must be weighed, therefore, in the light of these informations and must be carefully considered in implementing tax, tariff and credit policies for farm mechanization.

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# APPENDIX I-A

<u>Identity I</u>

$$(\Sigma A_i^1 Y_i^1 \; - \; \Sigma A_i^0 Y_i^0) \quad = \quad \Sigma \Delta A_i Y_i^1 \; - \; \Sigma A_i^0 \Delta Y_i$$

Proof:

$$\Sigma A_i^1 Y_i^1 - \Sigma A_i^0 Y_i^0 \quad = \quad \Sigma A_i^1 Y_i^1 \; - \Sigma A_i^0 Y_i^0 \; + \Sigma A_i^0 Y_i^1 - \Sigma A_i^0 Y_i^1$$

$$= \quad \Sigma (A_i^1 - A_i^0) Y_i^1 + \; \Sigma A_i^0 (Y_i^1 - Y_i^0)$$

$$= \quad \Sigma \Delta A_i Y_i^1 \; + \; \Sigma A_i^0 \Delta Y_i \qquad \text{Q.E.D.}$$

APPENDIX I-B

Identity II

$$(\Sigma A_i^1 P_i^1 X_i^1 - \Sigma A_i^0 P_i^0 X_i^0) = \Sigma \Delta A_i P_i^1 X_i^1 + \Sigma A_i^0 \Delta P_i X_i^1 + \Sigma A_i^0 P_i^0 \Delta X_i$$

Proof:

$$\begin{aligned}
\Sigma A_i^1 P_i^1 X_i^1 - \Sigma A_i^0 P_i^0 X_i^0 &= \Sigma A_i^1 P_i^1 X_i^1 - \Sigma A_i^0 P_i^0 X_i^0 + \Sigma A_i^0 P_i^1 X_i^1 - \Sigma A_i^0 P_i^1 X_i^1 \\
&= \Sigma (A_i^1 - A_i^0) P_i^1 X_i^1 + \Sigma A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0) \\
&= \Sigma \Delta A_i P_i^1 X_i^1 + \Sigma A_i^0 (P_i^1 X_i^1 - P_i^0 X_i^0 + P_i^0 X_i^1 - P_i^0 X_i^1) \\
&= \Sigma \Delta A_i P_i^1 X_i^1 + \Sigma A_i^0 (P_i^1 - P_i^0) X_i^1 + \Sigma A_i^0 P_i^0 (X_i^1 - X_i^0) \\
&= \Sigma \Delta A_i P_i^1 X_i^1 + \Sigma A_i^0 \Delta P_i X_i^1 + \Sigma A_i^0 P_i^0 \Delta X_i \qquad \text{Q.E.D.}
\end{aligned}$$

Identity III

$$(\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0) = \Sigma A_i^0P_i^0\Delta X_i + \Sigma\Delta A_iP_i^0\Delta X_i + \Sigma\Delta A_iP_i^0X_i^0$$
$$+\Sigma\Delta A_i\Delta P_i\Delta X_i + \Sigma\Delta A_i\Delta P_i X_i^0$$
$$+\Sigma A_i^0\Delta P_i\Delta X_i + \Sigma A_i^0\Delta P_iX_i^0$$

Proof:

$$\Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0 = \Sigma A_i^1P_i^1X_i^1 - \Sigma A_i^0P_i^0X_i^0 + \Sigma A_i^0P_i^1X_i^1 - \Sigma A_i^0P_i^1X_i^1$$
$$= \Sigma(A_i^1 - A_i^0)P_i^1X_i^1 + \Sigma A_i^0(P_i^1X_i^1 - P_i^0X_i^0)$$
$$= \Sigma\Delta A_iP_i^1X_i^1 + \Sigma A_i^0(P_i^1X_i^1 - P_i^0X_i^0 + P_i^0X_i^1 - P_i^0X_i^1)$$
$$= \Sigma\Delta A_iP_i^1X_i^1 + \Sigma A_i^0(P_i^1 - P_i^0)X_i^1 + \Sigma A_i^0P_i^0(X_i^1-X_i^0)$$
$$= \Sigma\Delta A_iP_i^1X_i^1 + \Sigma A_i^0\Delta P_iX_i^1 + \Sigma A_i^0P_i^0\Delta X_i$$
$$+ \Sigma\Delta A_iP_i^0X_i^0 - \Sigma\Delta A_iP_i^0X_i^0$$
$$= \Sigma\Delta A_i(P_i^1X_i^1 - P_i^0X_i^0) + \Sigma A_i^0\Delta P_iX_i^1 + \Sigma A_i^0P_i^0\Delta X_i$$
$$+ \Sigma\Delta A_iP_i^0X_i^0$$

$$= \Sigma\Delta A_i \Delta P_i X_i^1 + \Sigma\Delta A_i P_i^0 \Delta X_i + \Sigma A_i^0 \Delta P_i X_i^1$$

$$+ \Sigma A_i^0 P_i^0 \Delta X_i + \Sigma\Delta A_i P_i^0 X_i^0$$

$$= (\Sigma\Delta A_i \Delta P_i X_i^1 + \Sigma\Delta A_i \Delta P_i X_i^0 - \Sigma\Delta A_i \Delta P_i X_i^0)$$

$$+ \Sigma\Delta A_i P_i^0 \Delta X_i + (\Sigma A_i^0 \Delta P_i X_i^1 + \Sigma A_i^0 \Delta P_i X_i^0$$

$$- \Sigma A_i^0 \Delta P_i X_i^0) + \Sigma A_i^0 P_i^0 \Delta X_i + \Sigma\Delta A_i P_i^0 X_i^0$$

$$= \Sigma\Delta A_i \Delta P_i X_i^0 + \Sigma\Delta A_i \Delta P_i (X_i^1 - X_i^0) + \Sigma\Delta A_i P_i^0 \Delta X_i$$

$$+ \Sigma A_i^0 \Delta P_i X_i^0 + \Sigma A_i^0 \Delta P_i (X_i^1 - X_i^0) + \Sigma A_i^0 P_i^0 \Delta X_i$$

$$+ \Sigma\Delta A_i P_i^0 X_i^0$$

$$= \Sigma A_i^0 P_i^0 \Delta X_i + \Sigma\Delta A_i P_i^0 \Delta X_i + \Sigma\Delta A_i P_i^0 X_i^0 + \Sigma\Delta A_i \Delta P_i \Delta X_i$$

$$+ \Sigma\Delta A_i \Delta P_i X_i^0 + \Sigma A_i^0 \Delta P_i \Delta X_i + \Sigma A_i^0 \Delta P_i X_i^0 \qquad \text{Q.E.D.}$$

# APPENDIX II

Procedures for the Kruskal-Wallis Test*

1. Combine the k samples and rank all observations in a single series. The smallest score is replaced by rank 1, the next to smallest by rank 2, and the largest by rank N.

   N = the total number of independent observations in the k samples.

2. Add the ranks in each sample.

3. Apply the test using the formula below:

$$H = \frac{12}{N(N+1)} \sum \frac{R_j}{n_j} - 3\ (N + 1)$$

where: k = number of samples

$n_j$ = number of observations in $j^{\underline{th}}$ sample

N = $\sum n_j$, the number of observations in all samples combined

$R_j$ = Sum of ranks in $j^{\underline{th}}$ sample (column)

H is distributed approximately as chi square with K-1 degrees of freedom for sample sizes ($n_j$'s) sufficiently large.

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*Siegel, S. Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill Kogakusha, Ltd. 1956.

4. If $H > \chi^2_\alpha (k-1)$, where $\alpha$ is the level of significance, then reject the hypothesis that the K samples are actually from the same population and hence are significantly different from each other.

APPENDIX III

$$\log\left[\frac{Y_2}{Y_1}\right] = \log(1 + X) \approx X$$

where:

$$X = \frac{Y_2 - Y_1}{Y_1}$$

X approximately measures the percentage change in output if the higher order terms in the Taylor's Expansion Series are discarded since their values will be getting smaller and smaller for all $|X| < 1$, i.e.,

$$\log(1 + X) = X - \frac{X^2}{2} + \frac{X^3}{3} - \frac{X^4}{4} + \dots$$

# APPENDIX IV

Nitrogen content of organic 1/ and commercial 2/ fertilizers:

| commonly used commercial fertlizers | nitrogen content |
|---|---|
| a. urea | 45% |
| b. ammonium sulfate | 26% |
| c. ammonium chloride | 25% |
| d. 16-20-00 | 16% |
| e. complete | 14% |

| organic fertilizer (farm manures) | nitrogen content (lb./ton) |
|---|---|
| a. dairy cattle | 10.0 |
| b. feeder cattle | 11.9 |
| c. poultry | 29.9 |
| d. swine | 12.9 |
| e. horse | 14.9 |

1/ Brady N.C. The Nature and Properties of Soils , 8th edition MacMillan Publishing Co. Inc., New York: 1974, p.538

2/ Moran P. and Unson D. "Farm Survey and Recordkeeping Procedures for Consequences of Small Rice Farm Mechanization Project: Operation Handbook" IRRI/USAID, May 1980, p. 101.

# APPENDIX V

Procedures for the Chow's Test*

1. Run separate linearized regressions of production functions for mechanized and non-mechanized farms, i.e.

$$\log Y_m = \log A_m + B_1 \log F_m + B_2 \log L_m + B_3 \log K_m + B_4 \log C_m + U_m$$

$$\log Y_b = \log A_b + Z_1 \log F_b + Z_2 \log L_b + Z_3 \log K_b + Z_4 \log C_b + U_b$$

From these equations, obtain the error sum of squares $SSE_m$ and $SSE_b$ with degrees of freedom $N_m$-K and $N_b$-K respectively, where K is the number of parameters to be estimated. In this example, K = 4. Add these two error sum of squares:

$$SSE_s = (SSE_m + SSE_b) \qquad \text{with d.f. } (N_m + N_b - 2K)$$

2. Run another linearized production function combining all observations ($N_m + N_b$) and get the error sum of squares $SSE_t$ with ($N_m + N_b$ -K) degrees of freedom.

3. Get the difference between $SSE_t - SSE_s = SSE_d$

4. Apply the F-test:

$$F = \frac{SSE_d / K}{SSE_t / (N_m + N_b - 2K)}$$

with degrees of freedom K and ($N_m + N_b$ - 2K).

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*Gujarati, D. "Use of Dummy Variables in Testing for Equality Between Sets of Coefficients in Two Linear Regressions: A Note" The American Statistician, February, 1970, pp. 50-52.

5. If $F < F_{\alpha}$ , where $\alpha$ is the level of significance, accept the hypothesis that the parameters A's and B's are the same for the two sets of observations.

Testing for Structural Difference of the Sample's Production Functions Using Chow's Test:

A. Per hectare production functions derived from 2-wheel tractor versus carabao farms

| | | |
|---|---|---|
| $SSE_m = 5.74$ | d.f. = 51 | $N = 56$ |
| $SSE_b = 4.37$ | d.f. = 35 | $N_b = 40$ |
| $SSE_t = 13.98$ | d.f. = 91 | $N_t = 96$ |
| $SSE_s = 5.74 + 4.37$ | | $K = 4$ |
| $= 10.11$ | | d.f. = 88 |

$$SSE_d = 13.98 - 10.11$$

$$= 3.87$$

$$F = \frac{3.87/4}{10.11/88} = 8.42^{**}$$

$\alpha = 5\%$ $\qquad F_{(4,88)} = 2.49$

$\alpha = 1\%$ $\qquad F_{(4,88)} = 3.57$

---

**Significant at 1% level.

B. Per hectare production functions derived from 2-wheel/ 4-wheel tractor combination versus carabao farms.

$SSE_m$ = 7.49 d.f. = 15 $N_m$ = 20

$SSE_b$ = 4.37 d.f. = 35 $N_b$ = 40

$SSE_t$ = 13.37 d.f. = 55 $N_t$ = 60

$SSE_s$ = 7.49 + 4.37

= 11.86 d.f. = 52 K = 4

$SSE_d$ = 13.37 - 11.86

= 1.51

$$F = \frac{1.51/4}{11.86/52} = 1.65^{\text{n.s.}}$$

$\alpha = 5\%$ $F_{(4,52)} = 2.562$

$\alpha = 1\%$ $F_{(4,52)} = 3.722$

---

n. s. - not significant.